REMARKS

This amendment is responsive to the Official Action dated August 9, 2002.

Claims 1 - 44 were pending in the application.

No claims were allowed.

By way of this amendment, the Applicant has submitted a substitute specification and drawings, canceled claims 1-44 and entered new claims 45-72.

Accordingly, claims 45-72 are currently pending in the application.

Drawing Objection:

The drawings were objected to as lacking reference characters. Upon review of the specification and drawings, the Applicant has elected to provide a substitute specification and substitute drawing sheets which are believed to contain the correct references and better descriptions of the inventive subject matter. No new matter has been added.

Review and consideration of the substitute drawing sheets is respectfully solicited.

Claim Rejections under 35 USC §112:

Claim 1-44 were rejected under 35 USC §112 as being indefinite. Upon review of the claims as presented, Applicant has elected to cancel all of the pending claims in favor of new claims 45-72. The noted problems with claims 1-44 have been taken into account in the drafting of new claims 45-72. Withdrawal of the rejection is respectfully solicited.

Claims rejections under 35 USC §103:

Claims 1-44 were all rejected in view of various combinations of Kurobe '812, Kuczynski '686, Duthaler '304 and Scott '256.

As indicated above, claims 1-44 have been canceled in favor of new claims 45-72 which are believed to better define the invention.

Withdrawal of the Section 103 rejections, and review and consideration of new claims 45-72 is respectfully solicited.

Brief Discussion of the cited references and new claims:

The claimed inventions in this application address a problem that can occur in the packaging of VCSELs that has not been addressed in the prior art. One of the major advantages of VCSELs as lasers is the fact that they can be tested and characterized on-wafer to determine their suitability for packaging. This can be a great cost advantage. Unfortunately, some packaging procedures, such as encapsulation, necessarily change the device characteristics of typical VCSELs, making it difficult to predict the performance of packaged devices from the on-wafer performance. A question then arises. Can the devices be fabricated in such a way as to make the on-wafer performance the same as the packaged performance? This application presents a totally non-obvious affirmative answer to that question. *Surprisingly, the deposition of a pre-calculated thickness of just one extra layer of optically transparent material, atop the VCSEL, can adjust the reflectivity of the top VCSEL mirror, so as to make the on-wafer performance the same as the packaged performance.* Then, a second important question arises. Can the devices be fabricated in such a way as to not only make the on-wafer performance the same as the packaged performance, but to make both conform to tight predetermined specifications? Once again, this application presents a totally non-obvious affirmative answer. *The deposition of two different extra layers of optically transparent materials, atop the VCSEL, can adjust the reflectivity of the top VCSEL mirror, so as to make the on-wafer performance the same as the packaged performance, with both conforming to tight predetermined specifications.*

In the present patent application, the layer that matches the on-wafer device performance with the packaged device performance was originally referred to as a phase-matching layer. This terminology was somewhat ill chosen. The layer should have been more properly called a medium-matching layer, or an encapsulation medium matching layer. To better define the invention, the Applicant has taken the liberty of revising the specification so that the layer is consistently described as an encapsulation medium matching layer.

Phase-matching layers have been described in the prior art; they match the phases of the reflected components of an optical beam, propagating along an axis normal to the mirror layers, reflected from different parts of a hybrid mirror to maximize the reflectivity of that hybrid mirror by maximizing constructive interference. Examples of such phase matching

layers appear in the attached Remarks Figure 1, and as can be seen in that figure, these phase-matching layers are placed between two sections of a hybrid mirror and not atop the mirror. Kurobe et al (US patent 5,432,812) utilizes the type of phase-matching layer illustrated in Figure 1b. These phase-matching layers and their defined function in no way teach or suggest the possibility of a medium-matching layer and how it functions. Also, encapsulation as taught by Kuczynski (US patent 5,432,812), of the various device embodiments described in Kurobe et al (US patent 5,432,812), neither solves nor even addresses the problem addressed by the medium-matching layer described in our application. Also, using the materials described in Duthaler et al (US patent 6,312,304 B1) does not change the situation. Below is a detailed explanation of how the medium-matching layer functions.

VCSEL mirrors are Distributed Bragg Reflectors (DBR's), consisting of alternating layers of materials with different indices of refraction, with each layer a quarter-wave thick. Each interface, where the index changes, partially reflects an incident beam by an amount given by the equation, $R = (n_1 - n_2)^2 / (n_1 + n_2)^2$. The quarter-wave thickness of each layer is a phase-matching thickness, causing all the partial reflections to enjoy completely constructive interference, maximizing the reflectivity for the given number of interfaces. The last interface is between the last mirror layer and the medium into which the VCSEL launches light, which is usually air with an index of refraction $\cong 1$ (it is air during on-wafer testing). This last interface always makes a significant contribution to the total reflectivity of the top mirror. The reflectivity of the last interface depends only on the index of the last mirror layer and on the index of the medium, although the medium is not per se a part of the VCSEL structure. It does not depend on what is beneath the last layer, so for simplicity of discussion one can analyze the situation while having no other layers or interfaces below the last interface, making it the only interface between a substrate (with an index, n_s) and a medium (with an index, n_m) as is shown in Figure 3. If one changes the medium, as one does by encapsulating a device, then one necessarily changes the reflectivity of the last interface (as is shown in Figure 3), and in a VCSEL, one thereby changes the total reflectivity of a top mirror and so changes the device performance. This result appears to be inescapable.

The first primary invention described in our application, and again illustrated in the attached Figure 4, first of all recognizes that the last mirror layer (or equivalently the substrate

in Figure 4) can be covered by an additional layer to create two last interfaces, whose reflectivities need to be analyzed in tandem. The reflectivity of that pair of interfaces is a function of the reflectivities of each interface and of the phase angle between them, given by "k*d" (where d is thickness of the additional layer, and k is defined in Figure 4). The exact relationship is shown in Figure 5. At first sight, it appears that this is no solution. As the medium (that is the index of the medium) is changed, although the reflectivity of the lower interface does not change, the reflectivity of the upper interface does change, and to compensate for that change so as to keep the reflectivity of the tandem the same, it appears that one needs to change the phase angle, that is to change the thickness, d, of the additional layer, or its index (to change k). The second significant, unexpected insight in our application and the core of the first primary invention, is that for layers with a certain k, one can find a thickness, d, and thus a single phase angle "k*d", which yields the same reflectivity for the tandem of two interfaces, for two different mediums. Thus, for instance, such a "medium-matching" layer can yield the same reflectivity whether the medium is air, with an index, $n_a \cong 1$, or any encapsulant, with an index n_m.

It is thus submitted that the "medium-matching" layer functions very differently than the other phase-matching layers in the prior art and is no way anticipated by them. Even though the "medium-matching" layer yields the same reflectivity and thus the same performance for a device in two different mediums, it may not yield the "desired" reflectivity and performance. *The second important invention in this application is that a tuning layer can be placed between the last mirror layer and the "medium-matching" layer, so as to adjust the reflectivity to a particular value, which remains the same in two different mediums.* Scott et al (US patent 6,392,256) and a patent application cited therein ("Vertical Cavity Surface Emitting Lasers with Consistent Slope Efficiencies", Application # 09/237,580) disclose the use of a tuning layer, but only with it alone deposited on the last layer of the top mirror of a VCSEL, as shown in the attached Figure 2. Since the "medium-matching" layer and the tuning layer affect each other and each other's function, it is not obvious that they can be effectively combined. Also, their designs need to be different when combined than when separately deployed.

The new claims as presented are similar in scope to the previous claims with the interchange of the terms "phase matching" for "medium matching" and the addition of the requisite structure for interconnecting the discrete claimed elements.

Accordingly, claims 45-72 are believed to define patentable subject matter in view of the prior art cited.

Claims 45-72 are thus believed to be in condition for allowance and the application now ready for issue.

Corresponding action is respectfully solicited.

PTO is authorized to charge any additional fees incurred as a result of the filing hereof or credit any overpayment to our account #02-0900.

Respectfully submitted,

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